TOSHKA PROJECT IMPACTS ON WATER LEVELS AND DISCHARGES

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ABSTRACT

Toshka Project is one of the major and national irrigation projects planed to increase the cultivated areas in the south valley, improve the opportunity for better jobs and increase the income for the country. The project impacts and consequences should be studied carefully to maximize the intended benefits and reduce any expected side effects.

This paper is proposed to study the effect of the full operation of the project on the water levels and discharges down stream High Aswan Dam. This paper is considered a continuation for the author work to estimate the effect of low water levels on Irrigation pump station. The author has shared in previous work to estimate the effect of low water flow on pump station. On the other hand, this paper is focused on the effect of operating Toshka Project on this pump station. It is considered one of the first papers to discus this important subject. During this research, pump stations, for irrigation purposes, along the River Nile from Aswan to Cairo were reviewed according to their design and critical water level to determine the potential for expected problems due to passing low discharges in the four studied reaches from Aswan to Cairo which are Aswan-Esna, Esna-Naga Hammadi, Naga Hammadi-Assiut, and Assiut-Cairo.

A one-dimensional computer program based on solving the flow equations was developed to compute water levels related to the analyzed discharged. The model was developed using Visual Basic Computer language and then calibrated using the actual water level readings from gauging stating after developing the corresponding rating curve for each station. The computed water levels were compared to the design and critical pump station water level to determine the adequacy of the water level for pump station supply. The frequencies of different discharge were evaluated and the probability of the analyzed discharges was evaluated. Different flow cases were considered during this analysis and the resulted water level and discharge changes were highlighted. Conclusions and recommendations were presented as well.

Keywords: Toshka Project, River Nile Discharges, River Nile Water levels, Pump Stations.

INTRODUCTION

River Nile is one of the longest rivers in the world (about 6500 kilometers long). River Nile flood has a very great variation due to the different characteristics of the Nile Basin. The Nile flood can be as high as 150 (1878/1879) billion cubic meters per year and as low as 42 billion cubic meters per year (1913/1914). Both extreme cases, very low and very high, floods have their own side effects. While the very high floods have their side effects on river banks, hydraulic structures and riverbed, very low floods have their own side effects. Some examples of these side effects are the water supply un-sufficiency, navigation difficulties, and some local sedimentation problems. River Nile is divided into different reaches between major hydraulic structures. The river length between down stream Old Aswan Dam to upstream of Delta Barrages is divided into four reaches. From Aswan to Cairo and divided according to the major hydraulic structures such as Old Aswan Dam, Esna Barrages, Naga Hammadi Barrages, Assiut Barrages, and Delta Barrages.

The increasing demand for more cultivated areas necessitates the construction of new agricultural projects. Toshka Project is considered one of the largest projects ever established in Egypt to cultivate new areas in the southern part of Egypt. However, Toshka Project water subtraction from the water flow down stream High Aswan Dam should be studied carefully to be prepared for any side effects down stream High Aswan Dam.

This research paper is considered a continuation for the author work to estimate the effect of low water levels on Irrigation pump station. The author has shared in previous work to estimate the effect of low water flow on pump station, Aziz and Ismail, [1]. On the other hand, this paper is focused on the effect of operating Toshka Project on these pump station. It is considered one of the first papers to discus this important subject.

RIVER NILE DISCHARGES DOWNSTREAM ASWAN

The frequencies of River Nile discharges down stream Aswan for the period 1985-2004 are shown in figure 1. The discharges ranges are from a minimum value of 60 million cubic meters per day to a maximum value of 275 million cubic meters per day with an average discharge value of 158.71 million cubic meters per day. This study is concentrated on the effect of passing the lowest value (60 million cubic meters per day) down stream Aswan on the pump stations along the four reaches. This Value was recorded in December 1997.

The further effect of the operation of the Toshka Project on water levels along the four reaches will be computed. The pump station status after the project operation was considered as a case study for this paper. The proposed discharges for the four reaches are shown on Table 1, NRI, [4]. The computed probability of passing the 60 million cubic meters per day from the frequency occurrence is about 0.79%.

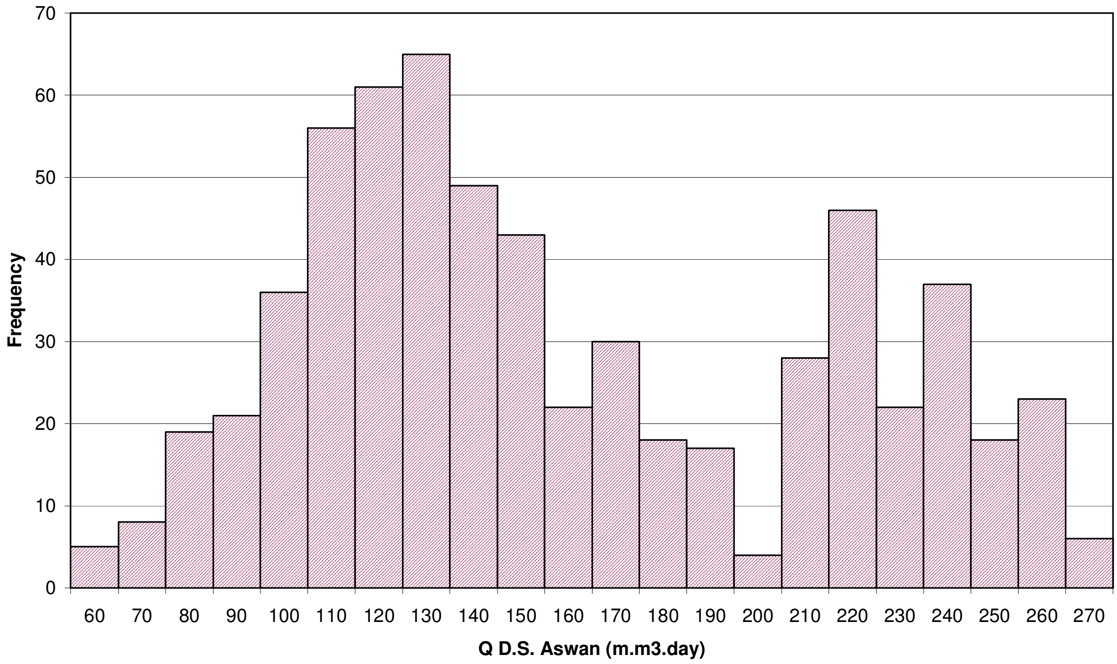

Figure (1) Frequencies of water discharges down stream Aswan (1985-2004)

Table 1. The proposed discharges for this analysis.

Reach	Proposed Discharge (million cubic meters per day)
1	60
2	50
3	40
4	37.7

TOSHKA PROJECT WATER HYDROGRAPH

The water requirements hydrograph was estimated by many authors, one of the first, and reliable, estimations was presented by Makary, Abdelbary, and Aziz [3]. The presented hydrograph for the project is shown in figure (2). After this early estimation, most of authors agreed about the total annual inflow for the full operation project ranging from 5 to 5.5 billion cubic meters per year. It can be shown from the figure that the discharge in December, related to the minimum considered value down stream Aswan of 60 million cubic meters per day, is 8 million cubic meters per day.

PROPOSED MATHEMATICAL MODEL

Mathematical models are used to predict water levels for different flood conditions. For this study, a mathematical model was derived based on solving the flow equations to compute water levels corresponding to different discharges. This model was developed using Visual Basic Computer language.

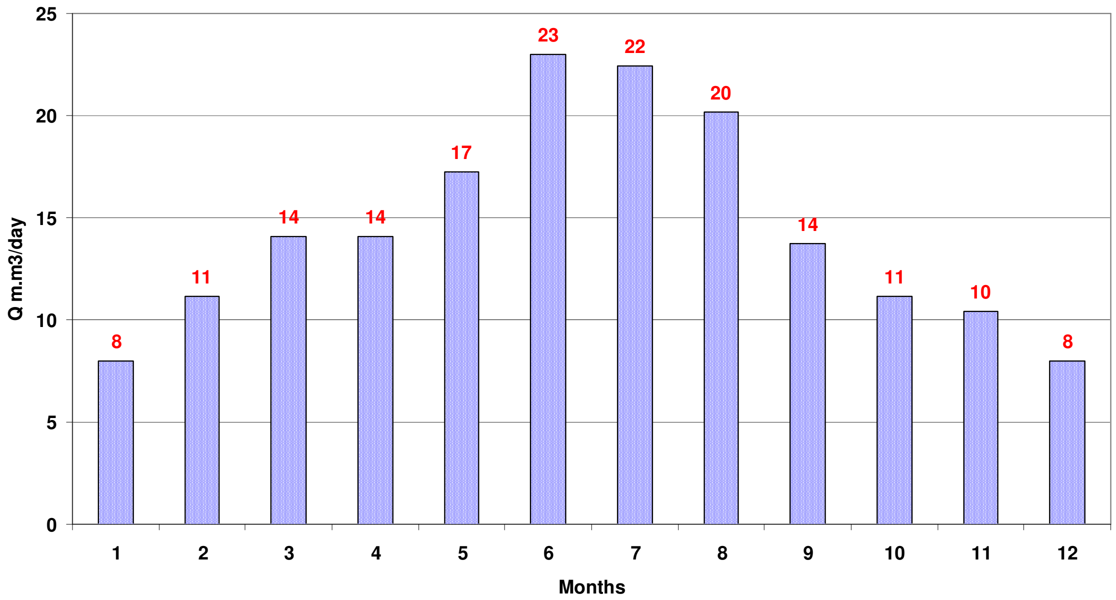

Figure (2) Toshka project proposed discharge

Water Surface Profile Computations

Water surface profile computations for the developed model are based upon solving the energy and the flow equations. The energy equation is described as follows:

$$\frac{V_1^2}{2g} + Y_1 + S_o \Delta L = \frac{V_2^2}{2g} + Y_2 + S_f \Delta L \qquad (1)$$

in which:

V_1 = Average velocity at section (1),
V_2 = Average velocity at section (2),
Y_1 = Water depth at section (1),
Y_2 = Water depth at section (2),
S_o = Bed slope,
S_f = Energy slope, and
ΔL = Distance between sections (1) and (2).

Manning flow equation is described as follows: (in metric units):

$$Q = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} A \qquad (2)$$

in which:

Q = Flow discharge,

n	=	Manning roughness,
R	=	Hydraulic radius (A / P),
S	=	Energy slope,
A	=	Cross sectional area, and
P	=	Wetted Perimeter.

The energy equation was solved numerically using Standard Step Method iterative procedure, Chow [2]. The downstream boundary condition was pre-determined from the actual measurements and the water surface profile computations were processed from downstream to upstream.

MODEL CALIBRATION

The model calibration is a very essential task in any mathematical model computations. The first step for the model calibration is to determine the actual measurements related to the analyzed discharges at the gauging stations. Different gauging stations along each reach were used for this calibration water. These gauging stations are shown on Table 2. Since the actual measurements are varied from time to time according to many factors, it was very important to develop a rating curve for each gauging station to be able to define its actual measurements related to different discharges in a more realistic way. These rating curves were developed for all the gauging stations and shown in Table 2.

Table 2. Selected water level gauging stations

No.	Site Name	Km	No.	Site Name	Km
R1-1	Gaafra	33.75	R3-5	Sohag	445.95
R1-2	Kom Ombo	49.65	R3-6	Koramata	457.6
R1-3	Ekleet	62.45	R3-7	Maragha	470
R1-4	Salwa Bahry	85.45	R3-8	Khazend	479.1
R1-5	Ramady	102.50	R3-9	Magris	509.5
R1-6	Baselea	131.00	R3-10	Aboteeg	520.5
R1-7	U.S. Esna	166.65	R3-11	Usassiut	544.78
R2-1	Ds Esna	166.65	R4-1	Ds Assiut	544.78
R2-2	Mateena	174.7	R4-2	Maaabda	576.2
R2-3	Armant	203.8	R4-3	Mandra	612.1
R2-4	Luxor	224.1	R4-4	Menia	687.55
R2-5	Hela	255.6	R4-5	Fadl	735.25
R2-6	Sherikia	264.9	R4-6	Beba	789
R2-7	Qena	286.7	R4-7	Baniswafe	808.6
R2-8	Naga Hamadi	346.45	R4-8	Korimate	839.1
R2-9	Us Naga	359.48	R4-9	Lethy	873.7
R3-1	Dsnaga	359.48	R4-10	Eksas	887
R3-2	Dom	363.2	R4-11	Roda	927
R3-3	Baliana	386.6	R4-12	Usdelta	953
R3-4	Gerga	405.1			

Figure (3) shows an example for a rating curve for one station (Armant Station). The results of the calibration process are shown as follows: Figure (4) shows the calibration results for Reach 1, Figure (5) shows the calibration results for Reach 2, while Figure (6) shows the calibration results for Reach 3, and Figure (7) shows the calibration results for Reach 4. From these figures it can be concluded that there is a close agreement between the measured and the predicted water levels and the predicted water level which can be used for the simulation process and to achieve the required analysis.

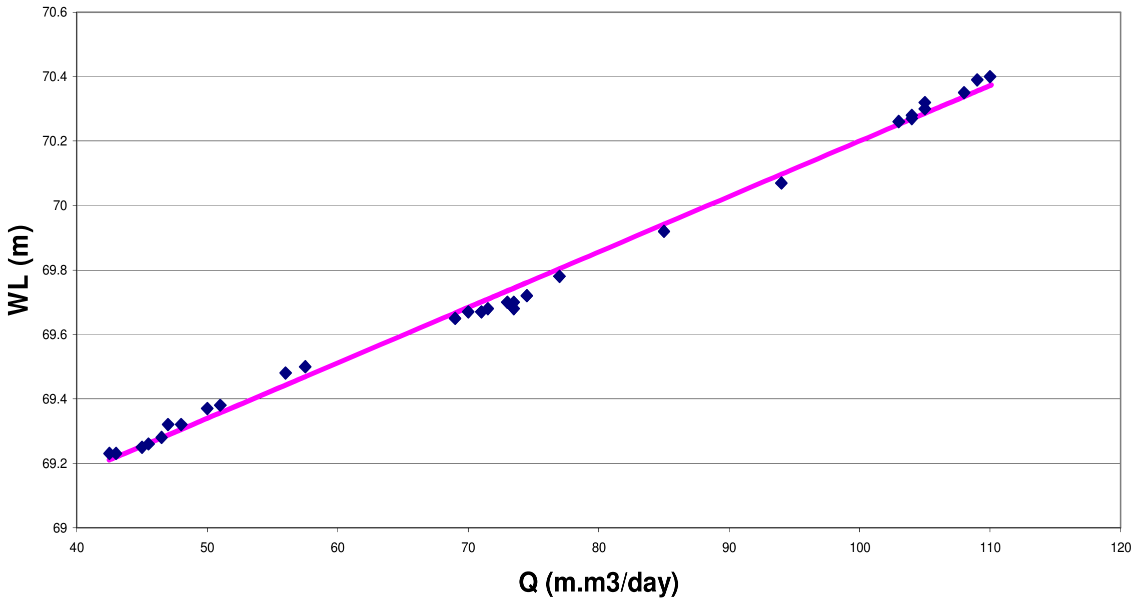

Figure (3) Armant gauging station rating curve for low discharges (Reach 2)

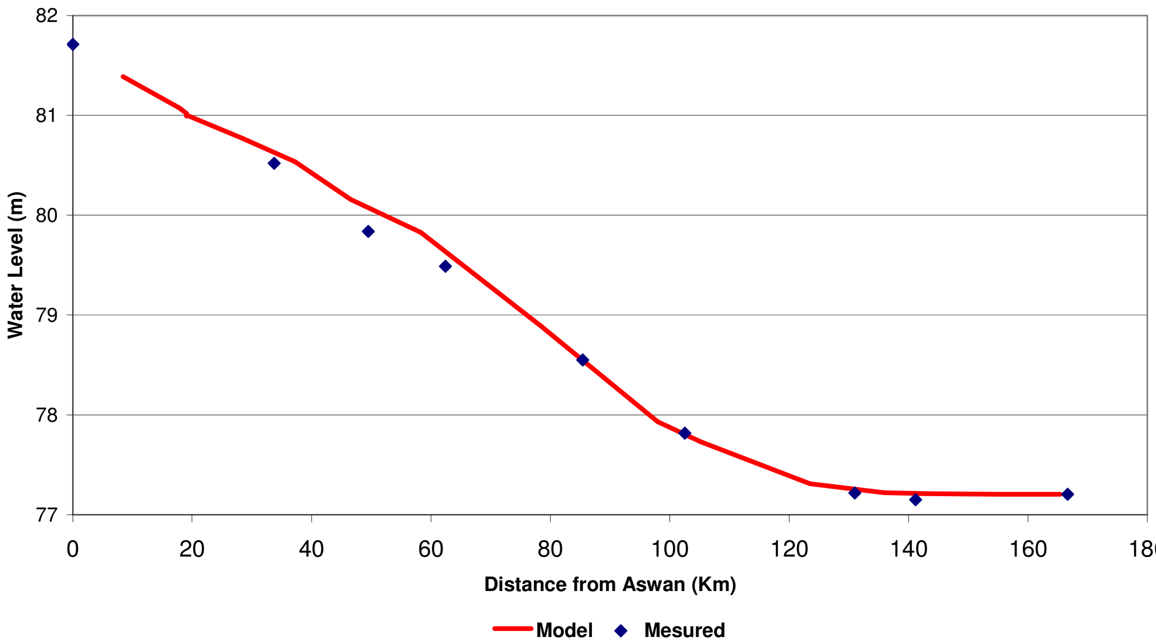

Figure (4) Reach 1 calibration curve (Q = 60 m.m^3/day)

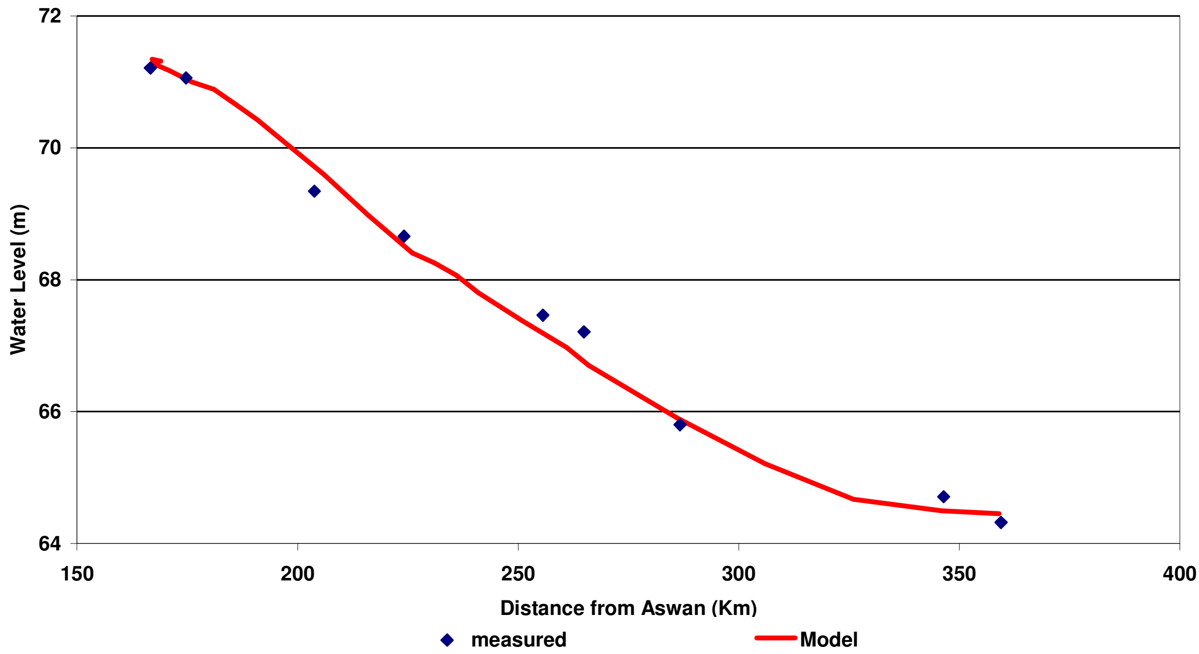

Figure (5) Reach 2 calibration curve (Q = 50 m.m^3/day)

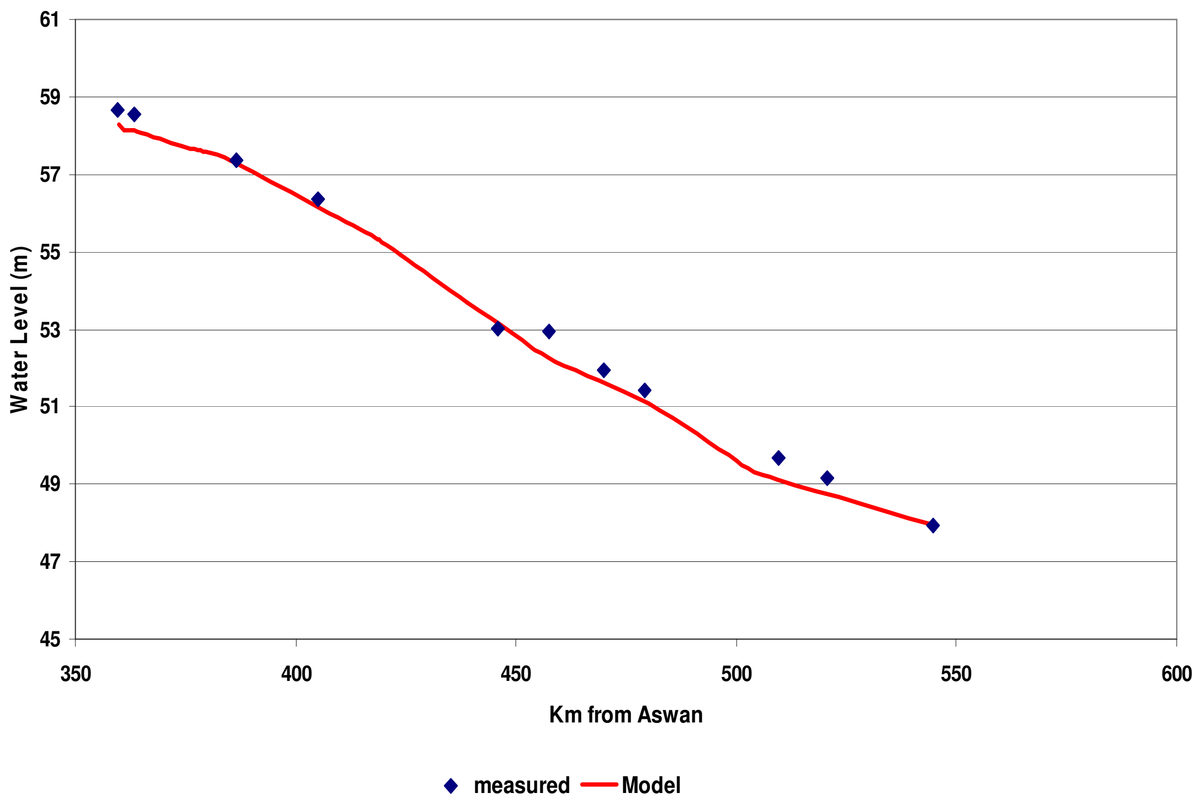

Figure (6) Reach 3 calibration curve (Q = 40 m.m^3/day)

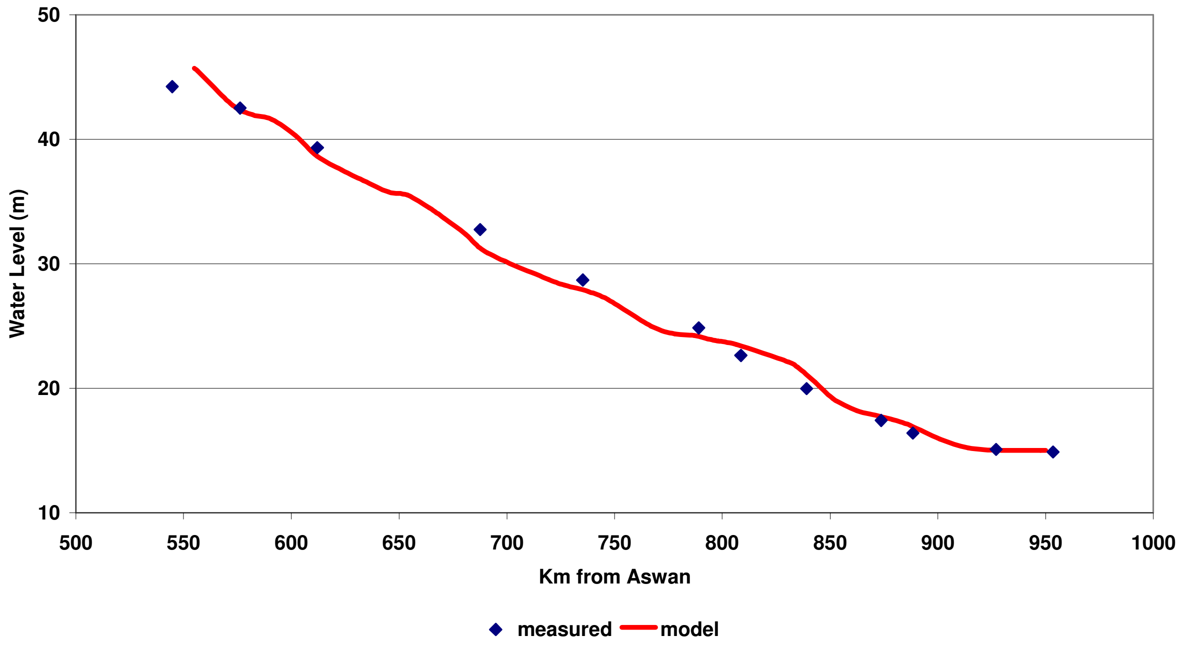

Figure (7) Reach 4 calibration curve (Q = 37.7 m.m^3/day)

WATER LEVEL COMPUTATIONS

The computed water levels for different cases mentioned in table 1 are shown in figures (8) to (11). Figure (8) shows the results for Reach 1. The computed water levels for a discharge of 60 million cubic meters per day along the reach are illustrated in the figure with the pump station and critical water level. The critical water level is defined as the minimum water level at which pump stations are able to operate.

Some of these stations are floating stations which can not relatively suffer from the low water levels. The stations with critical water higher than the computed water levels are expected to suffer from lack of water head. Figure (9) shows the results for Reach 2. The computed water levels for a discharge of 50 million cubic meters per day along the reach are illustrated in the figure with the pump station and critical water level. Figure (10) shows the results for Reach 3. The computed water levels for a discharge of 40 million cubic meters per day along the reach are illustrated in the figure with the pump station and critical water level. Figure (11) shows the results for Reach 4.

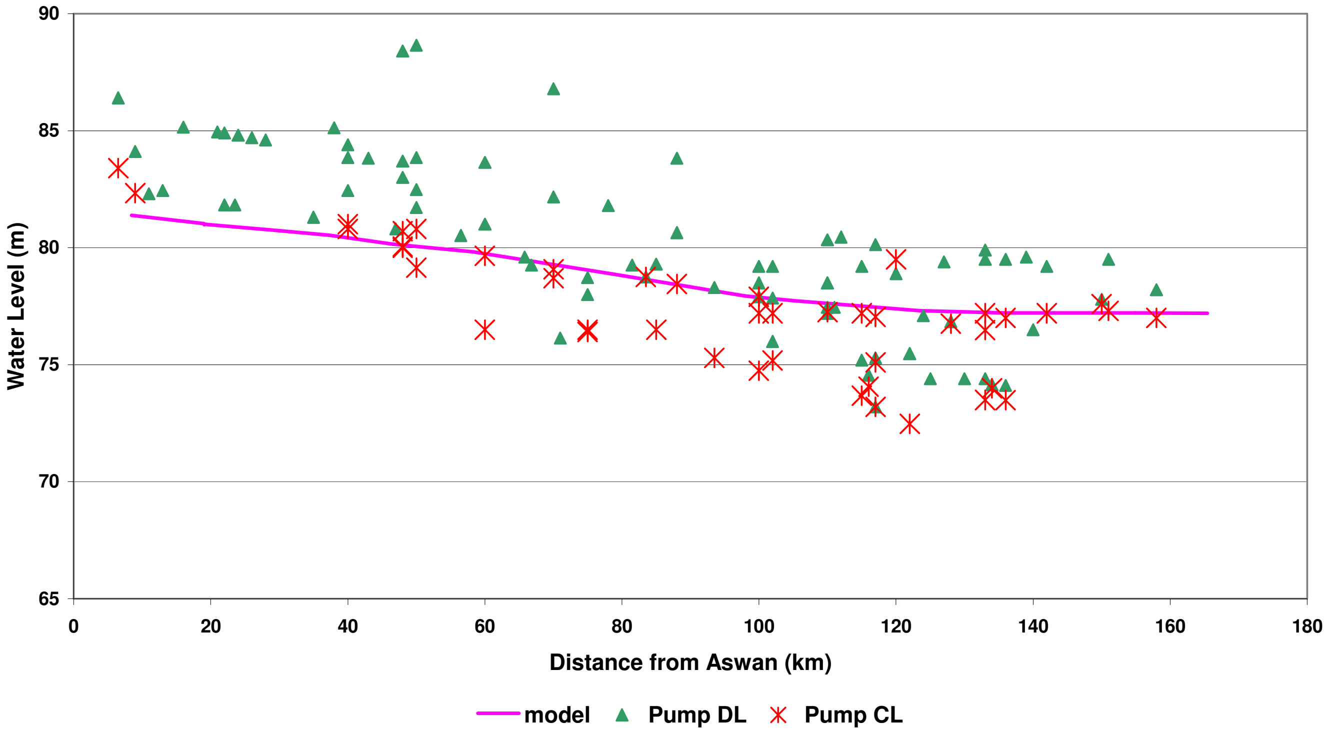

Figure (8) Analysis results for reach 1 (Q = 60 m.m^3/day)

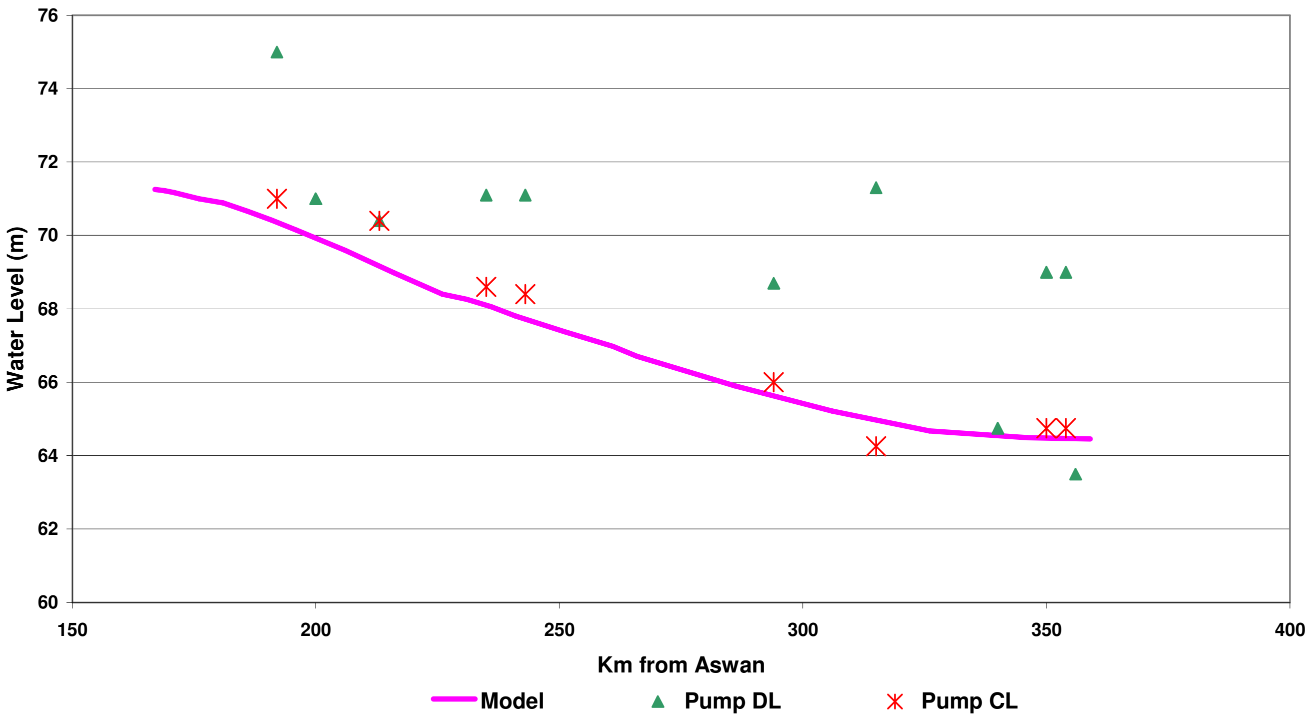

Figure (9) Analysis results for reach 2 (Q = 50 m.m^3/day)

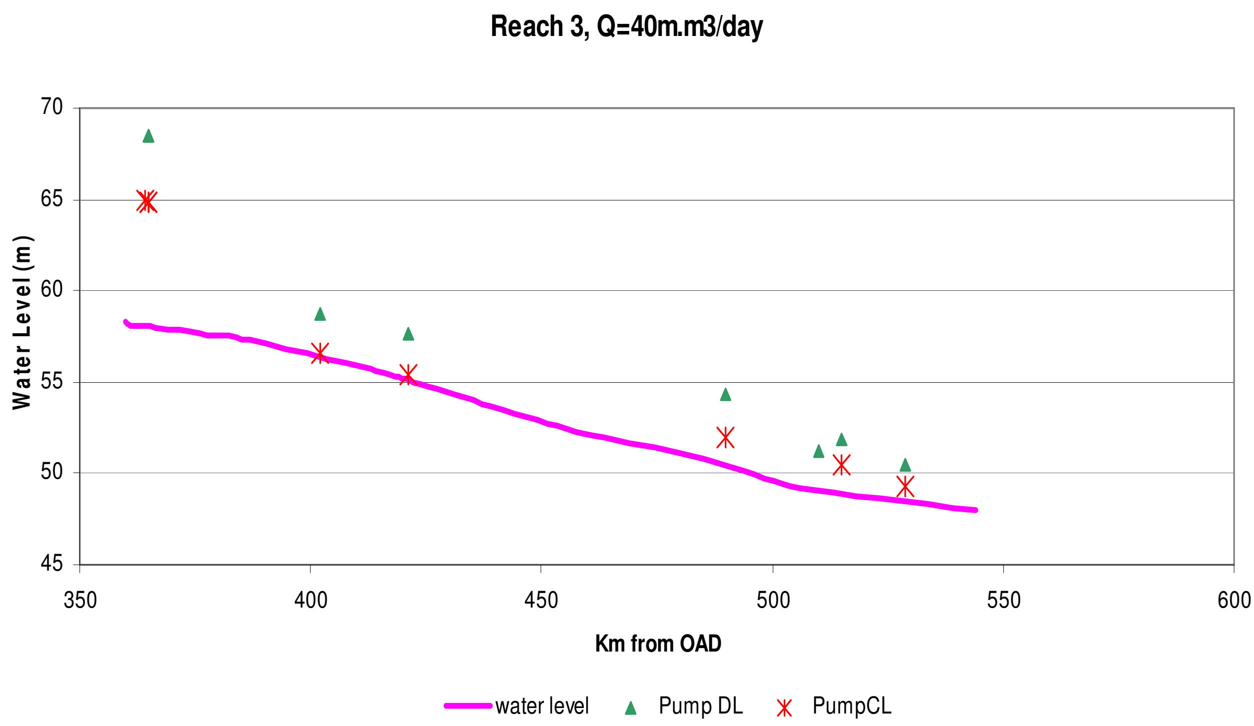

Figure (10) Analysis results for reach 3 (Q = 40 m.m^3/day)

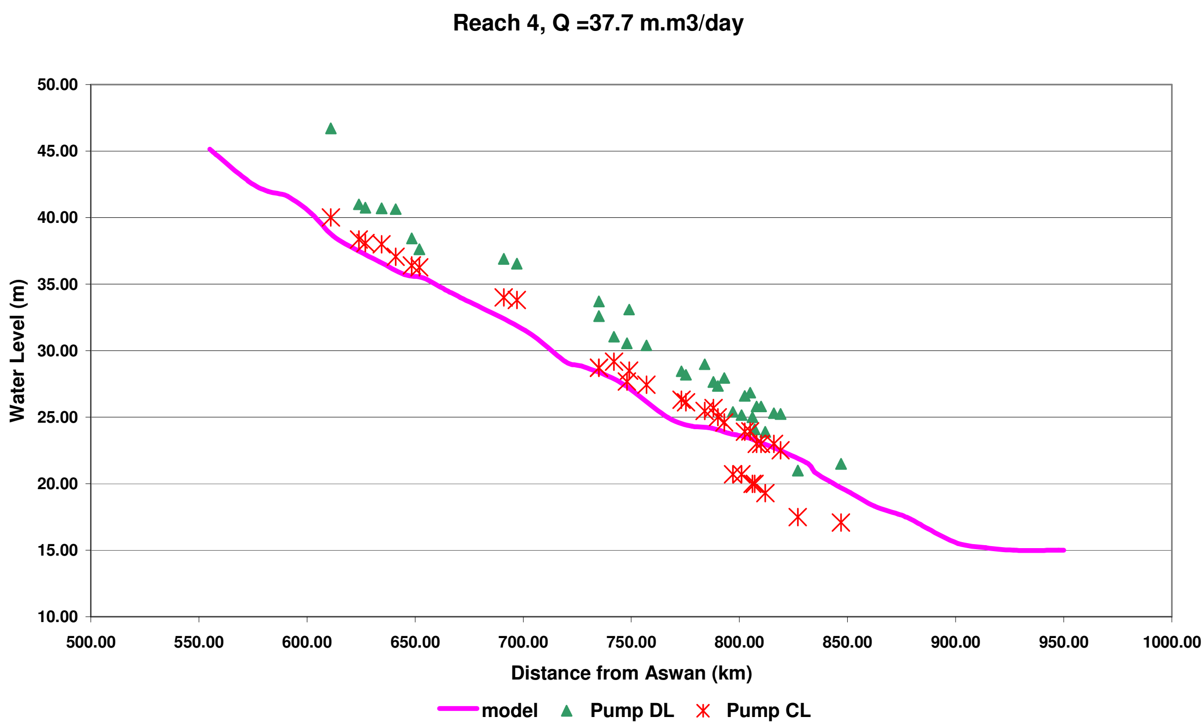

Figure (11) Analysis results for reach 4 (Q = 37.7 m.m^3/day)

The computed water levels for a discharge of 37.7 million cubic meters per day along the reach are illustrated on the figure with the pump station and critical water level. These figures show the water levels and the pump station status before operation of the Toshka Project. The effect of the project was taken, during this study, by the reduction of all discharges with the project discharge of 8 million cubic meters per day. This valley is related to the minimum considered value of discharge down stream Aswan Dam of 60 million cubic meters per day. The water levels were recomputed according to the newly reduced discharge. These discharges are shown in table 3. The model results for both cases, original and reduced discharges, are shown in figures (12) to (15). Figure (12) shows the results for reach 1, figure (13) shows the results for reach 2, figure (14) shows the results for reach 3, and figure (15) shows the results for reach 4.

Table 3. The proposed reduced discharges for this analysis.

Reach	Proposed Discharge (million cubic meters per day)
1	52
2	42
3	32
4	29.7

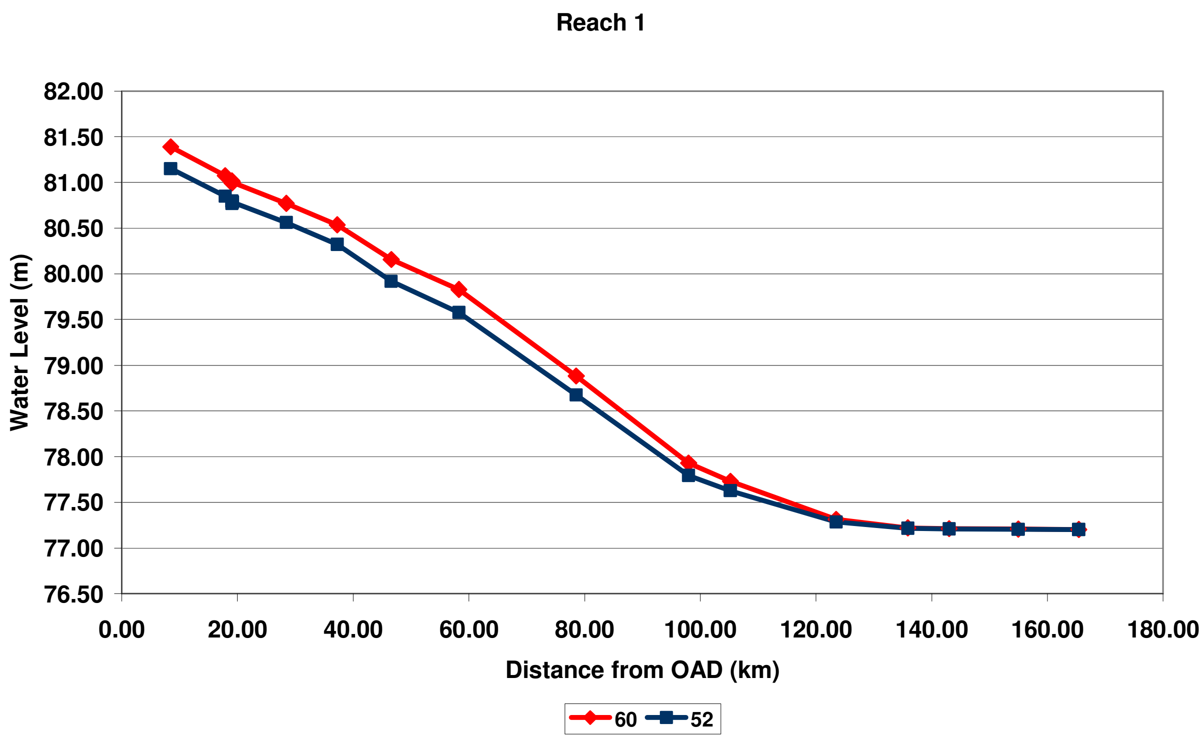

Figure (12) Analysis results for reach 1 for both discharges

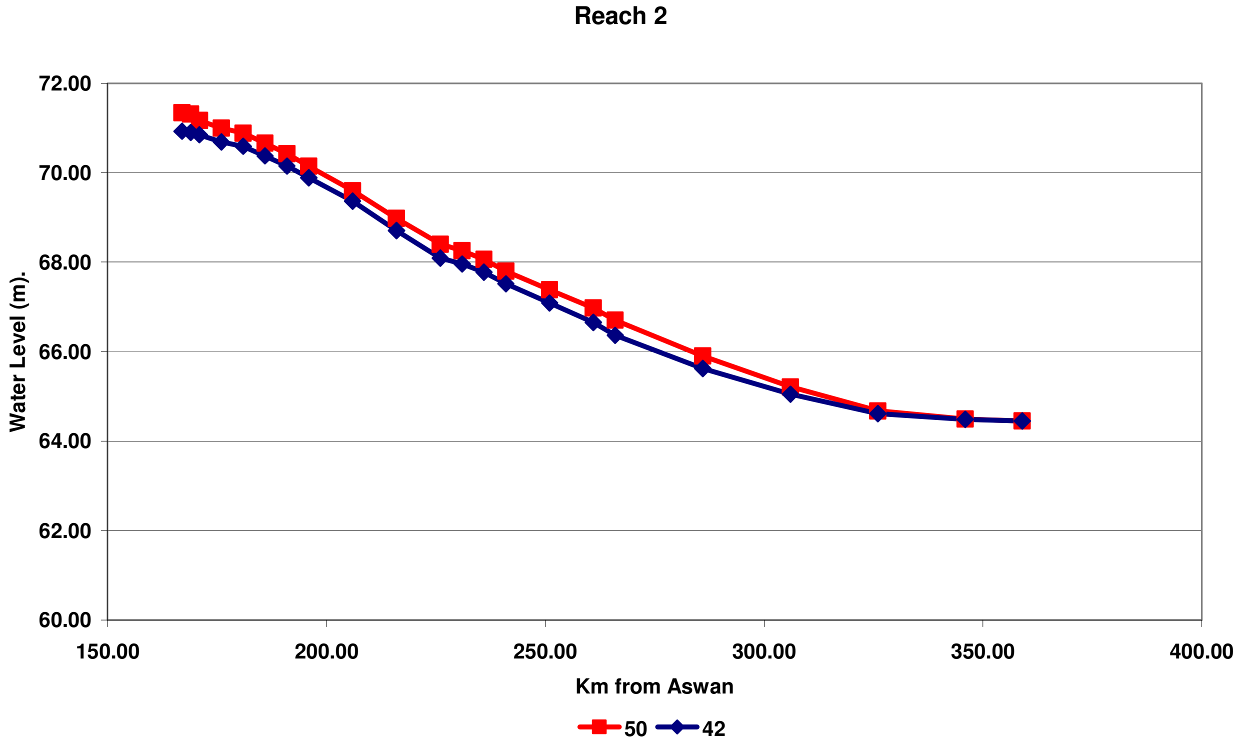

Figure (13) Analysis results for reach (2) for both discharges

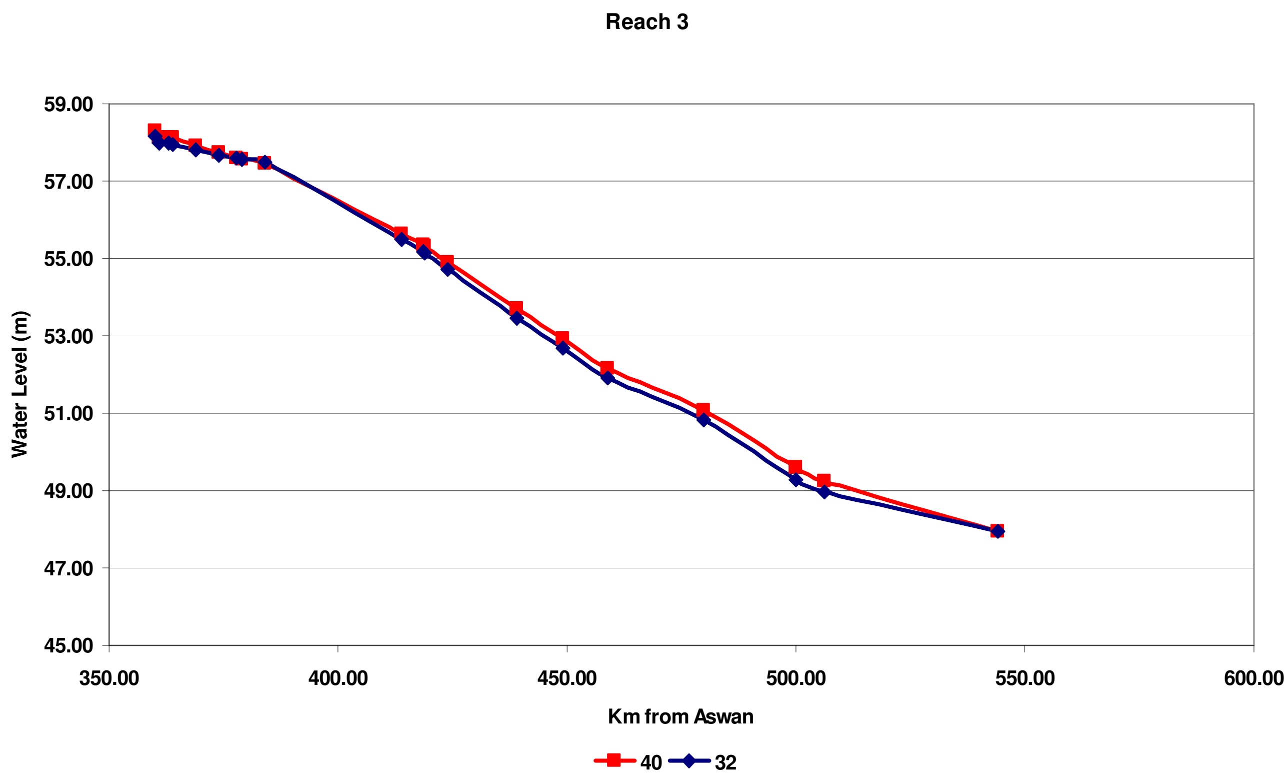

Figure (14) Analysis results for reach (3) for both discharges

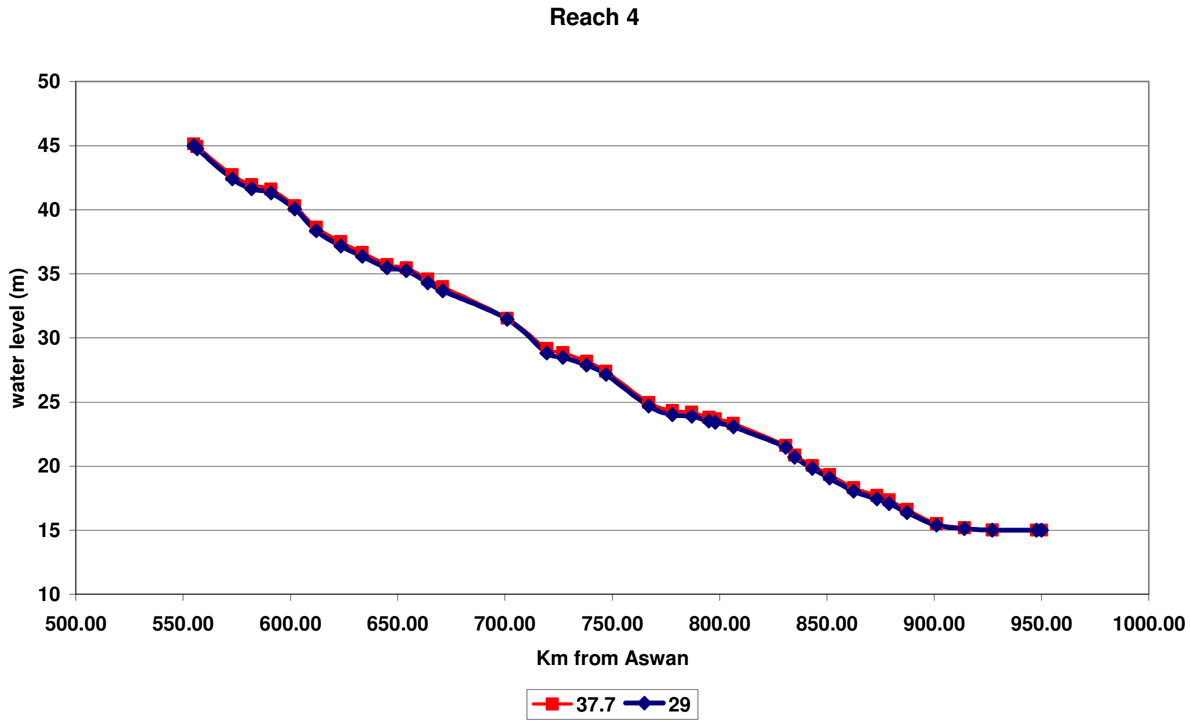

Figure (15) Analysis results for reach (4) for both discharges.

RESULTS OF THE ANALYSIS

The summary of the results is shown in Table 4. This table shows, for every reach, the analyzed discharge in addition to the total number of pump stations of each reach. It shows the observed number of stations which have a critical water level higher than the computed water levels due to the analyzed discharge. It shows also the maximum head difference between the critical and the computed water level for all pump stations in each reach. It has to be mentioned that Reach 3 has the highest percentage, 7 out of 9, (78% of the total pump station number). Figure (16) shows the comparison of the unsafe pump stations number before and after the full operation of El-Shikh Zayed for every reach. On the other hand, a detailed simulation was performed to obtain the required discharges to provide all the pumping station with enough water levels. It has to be mentioned here that some pump stations are only operating for high water levels. The results of this analysis show that the required discharges to cover all stations in the four reaches, even the high flow stations, are 140, 90, 90 ,90 m.m^3/day respectively. It can be concluded from the performed simulation that the required discharges to cover all stations are relatively high and can not be applied. Another alternative is to study the modification of these pump station intakes levels to reduce the critical water level for these stations.

Table 4. No. of critical pump stations before and after the project.

Reach No.	Total pump stations No.	Before El-Shikh Zayed			After El-Shikh Zayed		
		Q m.m^3/day	Critical pump No.	Max. head difference	Q m.m^3/day	Critical pump No.	Max. head difference
1	**81**	60	12	2.11	52	16	2.19
2	**12**	50	7	1.24	42	7	1.50
3	**9**	40	8	6.89	32	8	7.04
4	**36**	37.7	25	1.95	29.7	27	2.05

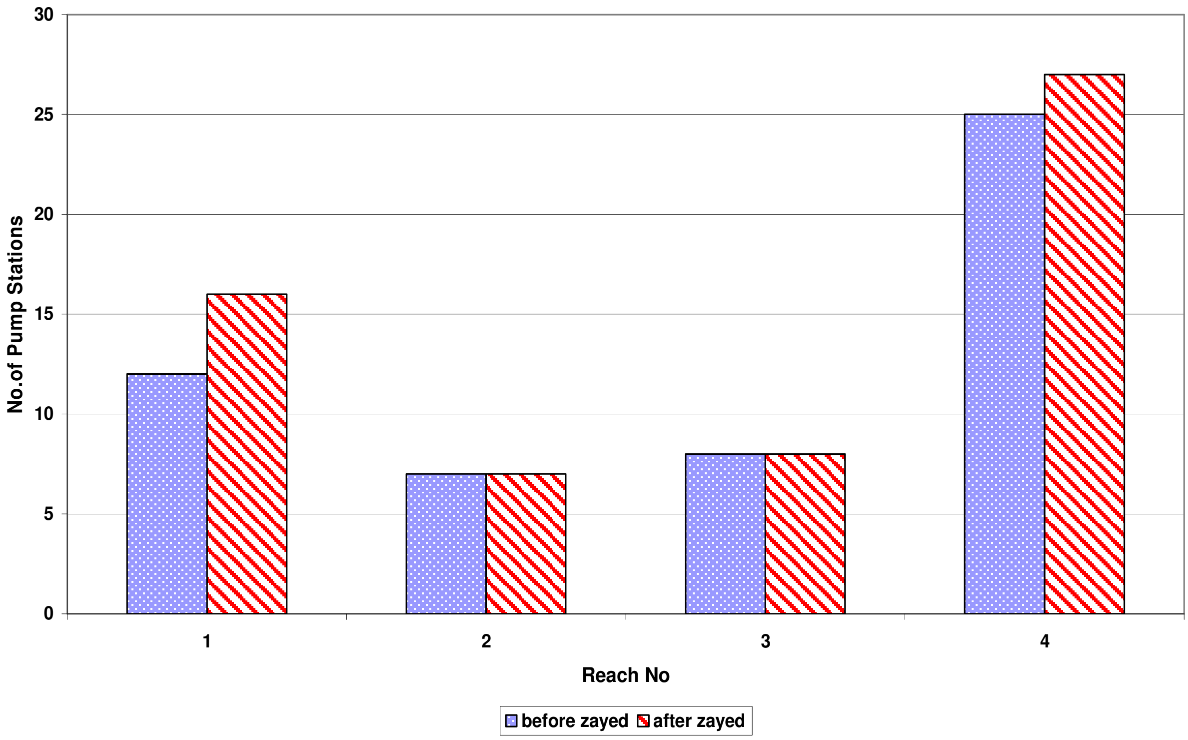

Figure (16) Comparison of unsafe pump stations for both cases.

CONCLUSIONS

During this research paper, different low discharges from Aswan to Cairo were considered for the four reaches Aswan-Esna, Esna-Naga-Hammadi, Naga-Hammdi-Assiut, and Assiut-Delta Barrages.

Recent Discharges for the period 1985-2004 were analyzed, from these discharges, the selection of lowest passed discharge downstream Aswan of 60 m.m^3/day (December 1997) was considered.

A scenario of passing the lowest discharges was considered as follows:

- Aswan-Esna is 60 m.m^3/day,
- Esna-Naga-Hammadi is 50 m.m^3/day,
- Naga-Hammdi-Assiut is 40 m.m^3/day, and
- Assiut-Delta Barrages is 37.7 m.m^3/day.

For the proposed hydrograph Toshka Project was used. The proposed December discharge (related to the considered 60 m. m^3/day) was estimated as 8 m.m^3/day.

Toshka project discharges were considered. Discharge reduction due to project operation and their effect on computed water level were studied and the related water level reductions were computed.

A one dimension mathematical model was developed and used to simulate the discharges and computed the related water level before and after the operation of El-shikh Zayed Project for the four reaches.

RECOMMENDATIONS

Further studies are recommended to analyze the effect of the operation of Toshka project on:

- All other types of stations for example (drinking water stations, power stations …etc),
- Navigation,
- Hydraulic structures.

Additional discharges scenarios for both Toshka project and D.S. High Aswan Dam should be studied too.

REFERENCES

1. Aziz, M., and Ismail, S., Nile River Low Discharge Effects on Pump Station Water Supply, Proceedings of the Seventh International Water Technology Conference (IWTC VII), Cairo, Egypt, 2003, pp. 523-534.
2. Chow, V.T. Open Channel Hydraulics, McGraw-Hill Book Co., New-York, pp. 680, 1957.
3. Makary, A., Abdelbary, M., and Aziz, M. Expected Nile Discharges and Water Levels Hydrographs after the Operation of El-Sheikh Zayed Canal (Toshka Project). International Conference on Integrated Management of Water Resources in the 21st Century, 1999.
4. NRI, Nile Research Institute Discharge Database Nile Research Institute, National Water research Center, El-Qanater, Egypt, 2006.